Transportation Trends That Drive New Thinking and Designs

Technologies for Truck and Bus, Automotive, Marine, and Rail

Parker

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The transportation industry continues to rapidly evolve. Daily, engineers need to meet new challenges, often by identifying and adopting new technologies. These new technologies are being shaped in response to growing concerns involving emissions and the environment, safety, fuel efficiency, and government regulations.

Certain trends are expected to dramatically impact many of its key segments including truck & bus, automotive, marine and rail. In the next five years, emissions standards, fuel efficiency/electrification, smart/connected vehicles, and autonomous vehicles are among the key trends that will alter the way the industry advances.

This white paper includes both global and U.S. market trends that are driving new thinking, designs, and technologies.

Heavy-Duty Trucks, Trailers, and Buses:

The Road Ahead

One of the most significant global trends that will affect new commercial trucks and buses is emission standards. Globally, emissions standards for heavy-duty vehicles (HDVs) have lagged those for cars and light-duty vehicles, but this is changing. In 2016, nearly 85% of light-duty vehicles were required to meet fuel economy standards, compared with only 50% of heavy-duty vehicles. By 2019, however, 70% of HDVs sold globally were in places with vehicle efficiency regulations.

In the U.S., the next two rounds of the Environmental Protection Agency's (EPA's) Greenhouse Gas emissions standards for commercial trucks and buses are scheduled to take effect in 2021 and 2024. They cover model years 2018-2027 for certain trailers, and model years 2021-2027 for all semi-trucks, large pickup trucks, vans, buses, and work trucks. Once implemented, these new standards will lower CO2 emissions and reduce fuel consumption.

While incremental technology is expected to meet the 2021 standards, **the 2024 standards pose a greater challenge for engineers.** The new rules will require emissions reductions of almost 20%. Among a variety of new technologies being considered, most heavy-duty truck OEMs are considering some type of 48-volt electric architecture to replace their current 12-volt systems.

They're also looking for ways to make trucks and trailers lighter. "The trend of light-weighting is gaining in importance due, in part, to battery weight," according to John Messina, Business Development Manager for Truck and Bus at Parker. "As trucks become electrified, one way to extend range is to increase the number of batteries. But that adds weight, so every pound of weight that can be removed from the truck is another pound of battery weight that can be added."

Trailers pulled by combination tractors are subject to new EPA regulations because their weight and drag are major contributors to the vehicle's carbon emissions and fuel consumption. Aerodynamic devices, lighter weight components and automatic tire inflation systems are being developed to reduce these effects.

Another global trend is the adoption of electric vehicles, particularly by urban public bus fleets. This trend began in China, whose cities currently operate 98% of all the electric buses in the world. This translates to 17% of the total city buses in the country. In comparison, about 10% of all the city buses in Europe were electric in 2019, with this share expected to reach 20% by the end of 2020. In the U.S., only 0.5% of all U.S. public transit buses were electric at the end of 2017, although 9% of all transit agencies either had some in service or had placed orders for them.

"California, by far, is most active state in electrification," said Chris Overmyer, Senior Field Application Engineer at Parker. "If you look at the LA basin, it has some of the worst air quality. They've pushed very hard to clean the air and adopt alternative fuel products. They recently approved the purchase of 95 electric buses with the goal of having a full electric fleet by 2030. But beyond electrification, we're also seeing the use of natural gas in the U.S. for its low emissions — 0.1 gram of nitrogen oxides (NOx) per gallon of fuel. The choice of alternative fuel is really dependent on the duty cycle of the engine and its destination." Natural gas is not as widely used in the European Union, for example.

Heavy-duty electric trucks are now being produced and sold in China, with other global manufacturers currently developing battery-powered and hydrogen fuel cell models. China has also introduced fleets of electric light commercial trucks powered by hydrogen fuel cells, with South Korea and Japan planning to use this technology in heavy-duty trucks. In late 2019, California and seven other states committed to speed the adoption of zero-emission medium-and heavy-duty vehicles.

Despite these newer technologies, diesel-powered trucks are still expected to comprise two-thirds of all new medium-and heavy-duty commercial trucks sold in the U.S. in 2040. This is mostly due to advancements being made in "clean diesel" fuel efficiency and in hybrid technology. Combined, they facilitate a zero-emissions operating mode within city limits, as a growing number of cities are enacting their own vehicle emissions restrictions. Soon, vehicles using non-diesel power sources will be utilized where it makes the most sense based on the location or job.

This includes fleets of smaller, battery-powered delivery trucks, and involves engineering considerations beyond just the vehicles. Overmyer said the electrification of a delivery truck requires a robust infrastructure. "It's not like a Tesla car that plugs into a 110-volt outlet and charges in four to six hours. With delivery vehicles, it's not just one going into your hub for charging. It's 10, 20, even hundreds of trucks that you're now plugging into the grid for charging at the same time. Infrastructure is critical."

The trend of added safety features in heavy-duty trucks will continue. This is being driven, in part, by the continued shortage of drivers, as safety features, such as predictive cruise control to handle traffic jams, are an important factor in attracting them. Another safety trend on newer trucks is real-time reporting, such as remote diagnostics and repair planning. This is made possible by the growth of connected-truck technologies.

Connected-truck technology, making trucks "smart vehicles," enables telematics systems in trucks to provide remote diagnostics, over-the-air software updates, and third-party software integrations. The future implementation of new over-the-air updates are expected to go beyond the engine to other truck components, such as the transmission. Advances in remote diagnostics have already reduced truck downtime by sending critical fault codes and nearby dealer repair locations to fleets.

"Daimler trucks are going to have 400 sensors collecting data. That data will inform drivers and fleet managers. We see this fault code—five minutes ago this is what happened, here's the dealership to go to for service, they have the needed part, and your appointment is scheduled," according to Overmyer. Messina adds, "The beauty of condition monitoring is that instead of just counting the miles, they actually monitor the engine or systems and tell you what maintenance is required based on the data."

Another major advantage of connected-truck technology is the digitalization of logistics. This growing trend electronically integrates individual trucks with freight shipping management functions, maximizing the productivity of every connected truck in a system and tracking every shipment in real time. It enabled faster transfers of goods in and out of distribution centers and reduced the number of trucks that make return trips empty. This technology has become critical to the success of efficient global freight delivery given that, on average, 85 million packages are being delivered worldwide every day. In addition, the logistics industry contributes 13% of all emissions worldwide and digitalization has the potential to reduce this by facilitating more deliveries using fewer trucks.

The trend of 3D printing is just reaching heavy-duty truck manufacturing but is used primarily for prototype parts because high volume requirements define the production process. The industry continues to seek strong materials with less weight and some parts suppliers are experimenting with 3D metal additives technology.

Fully autonomous trucks, meaning those with no driver in the cab, are not expected to be deployed until after 2030. In the meantime, the technology has evolved to where some companies are currently testing their prototype trucks on U.S. roads with a safety driver in the cab. One such company plans to test its trucks without drivers in 2021. Its autonomous trucks have a network of sensors, cameras and radar devices attached to the outside of the rig, all hardwired to an internal AI supercomputer that drives the truck.

These trucks will deploy slowly, possibly starting in industrial areas such as company terminals, logistics centers and ports, all contained areas without public access. For eventual entry into the commercial trucking industry, projected to happen around 2025, they will all have safety drivers on board and will be used in specific cases. An example would be long distance, on-ramp to off-ramp or hub-to-hub trips. The driver will still have to handle the initial loading and final delivery, which are not yet automated.

The growth of premium-class intercity bus services in the U.S. is another trend affecting bus design. For a premium price, many of these buses feature 2x1 vs. the traditional 2x2 seating, and much like first-class European train cars, they may offer entertainment streaming, full bathrooms, food and beverage service, private sleeping cabins, a lounge, on-board attendants, table seating, and reclining seats. These buses are attracting new, more affluent customers, including those who would otherwise fly.

Rail:
On Track for a Busy Future

Global demand for rail services, including both passenger and freight, are projected to more than double by 2050. There are three main types of passenger rail: urban, high-speed, and conventional. Urban includes light rail and metro (subway) systems and conventional rail includes suburban and intercity passenger systems. Of the three types, urban and high-speed rail have been growing rapidly for the past decade, including the infrastructures that support them.

The world's passenger rail systems are concentrated in China, the European Union, India, Japan, and Russia, collectively representing 90% of all global passenger rail activity. More than 40 cities in China now have metro systems, surpassing other countries.

High-speed trains are generally defined as those that travel faster than 160 mph on new train lines and 120 mph on existing lines. Today's fastest conventional high-speed trains are in China and travel up to 217 mph. China, Japan, and South Korea also have a small number of maglev (magnetic levitation) systems, which travel up to 270 mph. Three new maglev systems are currently under construction in China and Japan. The new Hyperloop technology (traveling through a sealed tube) has not yet been used in an operational commercial system and may prove cost prohibitive.

Many European countries have high-speed rail networks, with the largest in France, Spain, Germany, Sweden, the UK, and Italy. The European Union has stated its goal to develop a trans-European high-speed rail network. Two other countries with the largest high-speed rail systems are Japan and South Korea but China has the largest in the world, with nearly 27,000 kilometers of track in operation, far exceeding (#2) France's 3,220 kilometers. China's high-speed rail, now carrying over twice as many passengers as its domestic airlines, has resulted in airfare cuts and cancellations of short regional flights.

The U.S. has yet to build a fully high-speed rail line although several are finally in the works. The largest is a $20 billion high-speed line now under construction in California, scheduled to connect Anaheim to San Francisco in 2033. Virgin Trains USA is currently building a high-speed rail system connecting Miami to Orlando and Walt Disney World, scheduled for completion in December 2022. Virgin Trains USA also plans to start construction in late 2020 on a $5 billion high-speed line between Los Angeles and Las Vegas, with trains running by 2023. After these, the next likely project is a $20 billion "Bullet Train" between Houston and Dallas, with construction possibly starting in 2021 or 2022.

As in other transportation segments, **electrification is a continuing global trend.** All urban and high-speed rail systems are electric by design, except for a few light rail systems in Europe and North America that use diesel-powered trains. Overhead lines supply power to most light rail systems, while metro systems typically use an electrified third rail. Outside of these types, electrification in the rail industry pertains to the power choice for new train lines to be electric rather than diesel and for the conversion of existing trains and track from diesel to electric.

The two drivers of global rail electrification are upgrades of passenger rail systems and government regulations for the reduction of carbon emissions produced by diesel fuel. Overall, only about one-fourth of the world's total rail miles are electrified, including both passenger and freight, the latter of which tend to use diesel-powered trains. Other regions of the world are significantly ahead of North America in rail electrification: 57% in Western Europe and 47% in Asia compared with only 1% in North America. This dichotomy is primarily due to North America having the longest rail line network in the world, mostly single track, and mostly used for transporting freight rather than passengers. Unlike Europe, a major reason that trans-regional passenger rail has failed to develop in North America is the long distances between commercial centers; thus air transport is preferred.

Compared with other major forms of transportation, rail is the most advanced in terms of autonomous operation. There are now semi and fully driverless subway and light rail systems in cities throughout the world, mostly in Asia and Europe, while the U.S. is far behind in deploying them. Nearly all fully automated

rail systems in the U.S. are people movers at major airports or similar short track systems in a handful of cities, like Las Vegas. The only cities in North America with large driverless systems are San Francisco (BART), Miami (Metromover), and Vancouver, British Columbia (SkyTrain), all light rail. There are also semi-autonomous metro systems that, for safety reasons, require a driver to be present.

The rail industry is undergoing a **technological transformation as a result of automation, digitalization, and the rise of Big Data and IoT.** Highlights of these in the U.S. include:

Positive Train Control (PTC) – PTC is an automated safety system, federally mandated in 2008 with a final deadline of December 31, 2020 for implementation. It applies to the country's largest freight railroads (Class 1), which own most tracks in North America. According to the U.S. Federal Railroad Administration, "PTC systems use communication-based and processor-based train control technology to prevent train-to-train collisions, overspeed derailments, incursions into established work zone limits, and movement of trains through switches in the wrong position." As of January 2020, PTC was already operational on 98.5% of the required routes nationwide.

The next generation of PTC is expected to know the exact location of every train in the network and the distance needed between each one to operate safely. This will enable railroads to safely increase the number of trains operating on the same track.

Advanced fuel management systems automatically assess numerous internal and external factors to maximize fuel efficiency for an individual train and its cargo.

Inspection and sensor technology include automated equipment that monitors numerous aspects of track integrity, smart sensors positioned along tracks that identify worn components on passing trains for predictive maintenance, and hundreds of sensors generating thousands of train performance readings per minute. These systems amass Big Data in real time, which railroads assess using advanced analytics software to ultimately improve rail safety, efficiency, and reliability, while reducing costs.

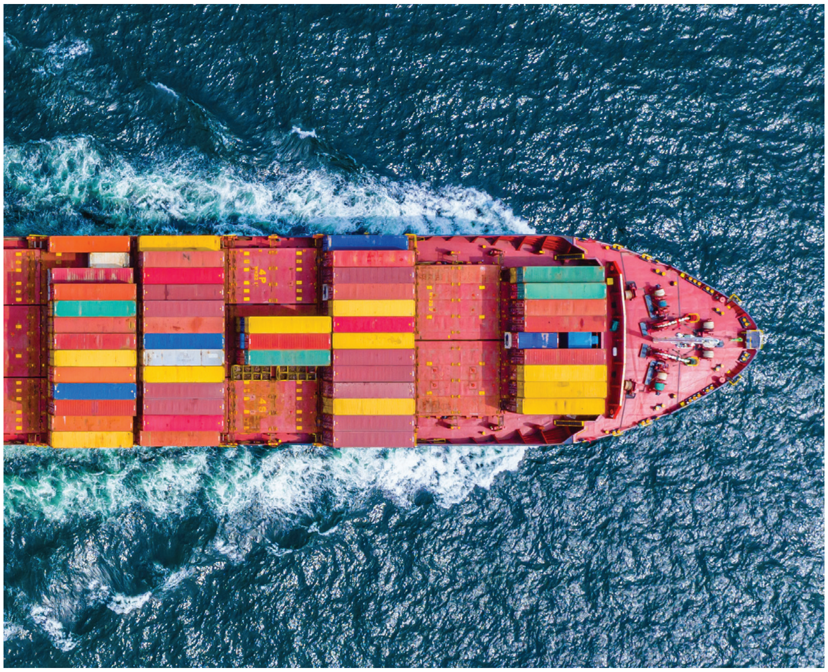
The Internet of Things (IoT) is leading to the ability to create a "digital twin" of a critical rail asset in order to replicate the performance of the real asset and offer real-time analytics and insights on how it is functioning and any potential issues.

The rail industry's growing digital infrastructure has increased its exposure to cyber threats. In Europe, several cyber-security firms have worked with the EU Agency for Railways (ERA) and the European Union Agency for Cybersecurity (ENISA) to create the European Railway Information Sharing and Analysis Centre (ER-ISAC). Its purpose is to create a secure and confidential platform for information sharing across the European railway industry about incidents, threats, and methods for improving security. ER-ISAC has become one of the primary organizations addressing cybersecurity in the European railway industry.

Marine:
The Tides Are Changing

Recent environmental regulations are strongly impacting the international marine shipping industry. The International Maritime Organization (IMO) regulates international shipping and its *International Convention for the Prevention of Pollution from Ships* ("MARPOL") has now been signed by 156 flag states, which represent 99.4% of the world's shipping tonnage.

In April 2018, the IMO adopted a strategy for **reducing greenhouse gas emissions from international shipping,** the first global climate framework for this industry. It covers both new and existing oceangoing vessels. Compared with 2008 levels, it sets a 40% greenhouse gas (GHG) reduction target for carbon intensity by 2030 and a reduction by at least 50% by 2050. This presents both great challenges and opportunities for innovation.



The IMO has also set **a new a cap on the sulfur content of fuel used on most commercial ships** to further cut sulfur oxide (SOx) emissions, a major environmental pollutant. Since 2012, the maximum limit had been 3.5% sulfur content but the new cap, effective **January 1, 2020,** is 0.5%.

There are several ways for ships to meet these requirements in the short term, such as switching to more expensive low-carbon and low-sulfur fossil fuels. Another option currently being used is onboard exhaust gas cleaning systems (EGCS) or "scrubbers" that remove harmful pollutants from burning higher carbon fuels before they are released into the air. Other measures proposed by the IMO to improve fuel efficiency, thus lowering ships' carbon emissions, include energy efficient design improvements of new vessels, improved operational efficiency, and vessel speed reduction.

An increasing number of large ships, including container ships and cruise ships, are being built to run on liquified natural gas, which can reduce CO2 emissions by 25-30% and SOx by up to 90% compared with conventional heavy fuel oil and marine diesel oil. LNG retrofits of existing vessels, however, are costly. LNG fuel requires onboard cryogenic storage tanks that smaller vessels cannot accommodate. The consensus is that in the near term, many ships with large bore diesel engines will use "dual fuels," both LNG and conventional marine fuels, to satisfy environmental regulations.
One global oil company predicts that by 2040, 12% of all shipping fuel will be LNG. In addition, some European companies are already working to develop **future propulsion systems that run on hydrogen- and ammonia-based marine fuels** to meet 2050 emissions limits.

One of most unique new propulsion systems is an ancient one: wind. A Swedish shipbuilder has developed a wind-powered prototype of a 35,000-ton oceangoing car carrier. It has vertical telescopic sails made of steel and composite materials, which are the tallest sails ever constructed. Able to cross the Atlantic in 12 days carrying 7,000 cars, the ship will emit 90% less CO2 than conventional car carriers. The full-size version is scheduled to launch in 2024, according to an October 2020 CNN travel article.

Another growing environmental issue for ships relates to their ballast water. This is seawater pumped into and out of storage tanks to compensate for weight changes in the cargo, fuel, and water they carry. Ballast reduces stress on the hull and provides stability when ships are at sea. Unfortunately, this practice has led to the uptake of harmful aquatic organisms, including invasive species, and their subsequent discharge into marine environments elsewhere in the world.

In 2017, a Convention of the International Maritime Organization went into effect requiring all international seagoing ships to exchange any ballast water taken in at their last port with fresh seawater, at least 200 miles from shore. **A new, stricter Convention is scheduled to go into effect in 2024** that will require these ships to either use an onboard ballast water treatment system or to discharge their ballast water at an approved facility on shore.

All oceangoing cargo vessels, military ships, cruise ships, and many smaller ships and large yachts have onboard systems that convert seawater into potable water. "In the old days, vessels that were out to sea for extended periods filled their large water storage tanks in port before sailing. Now, thanks to water filtration technology, ships and pleasure craft alike are improving their sustainability and safety by making their own fresh water on-demand," says Paul Kamel, water purification Product Manager II with Parker. "They have an endless supply of safe, fresh water and can free up space and weight of water storage for other uses."

Marine desalination systems rely on one of two basic technologies: thermal distillation or reverse osmosis (RO). A thermal distillation system boils seawater using the ship's waste steam and heat from its engines. The steam then condenses into distilled purified water, leaving behind the salt and other impurities.

Reverse osmosis, instead of using heat, uses energy to pump seawater through semi-permeable membranes, which filters out everything but pure water. Because thermal distillation requires very large diesel engines to supply the heat needed, vessels with smaller engines use reverse osmosis to generate clean water. Many large ships, however, have both types of systems.

There is a **trend toward smaller cruise ships choosing reverse** osmosis over thermal systems for both new ships and retrofits. New RO systems use more compact equipment so have a smaller footprint. They also are easy to install and maintain and they require less energy that earlier RO systems.

Rapidly growing global demand for clean water is pushing engineers to **develop improved desalination technologies** that will deliver higher performance and lower costs. Kamel says this technology is finding land-based applications, such as large containerized systems used for natural disaster relief, and compact, easily transportable systems used by the military and first responders on missions in remote locales where fresh water isn't readily available.

Marine systems will benefit because both land-based and ship-based systems use the same two basic technologies. Research is underway on new membrane materials, such as graphene, carbon nanotubes, and mixed matrix materials. Other research is exploring chemical methods of extracting salt, and thermal systems powered by renewable energy.

Automotive:
Going More Than the Extra Mile

The global growth of electric vehicles is being driven by the transition to non-polluting transportation, stimulated by government policies such as fuel economy standards and incentives for zero- and low-emission vehicles. Cities in Europe, India, and Asia, for example, are moving toward total bans on internal combustion engines in their city centers. Governments around the world also are adopting measures to ensure publicly accessible chargers in cities and on highways.

In the U.S., the state of California recently announced that by 2035 it will require every new passenger car and truck sold in the state to be electric-powered or otherwise have "zero emissions." California currently represents about half the U.S. market for electric and hybrid vehicles and is considered a leader that other states follow in adopting new automotive standards and technologies.

While electric cars still represent less than 3% of global car sales, the number of electric vehicles in service worldwide grew 63% in 2018 over 2017 to more than 5.1 million, with an additional 2.1 million (+41%) sold in 2019. Battery electric cars and plug-in hybrids comprised nearly three-fourths of all electric cars sold in 2019. Hybrid electric vehicles, powered by both electricity and gasoline, represented the rest.

Nearly half (47%) of all electric cars on the road are in China compared with only 8% in 2013. Of the remainder, 24% are in Europe, 22% are in the U.S., and 7% are in other countries. Additionally, the total number of global charging stations was approximately 5.2 million in 2018, an annual increase of 44% over 2017.

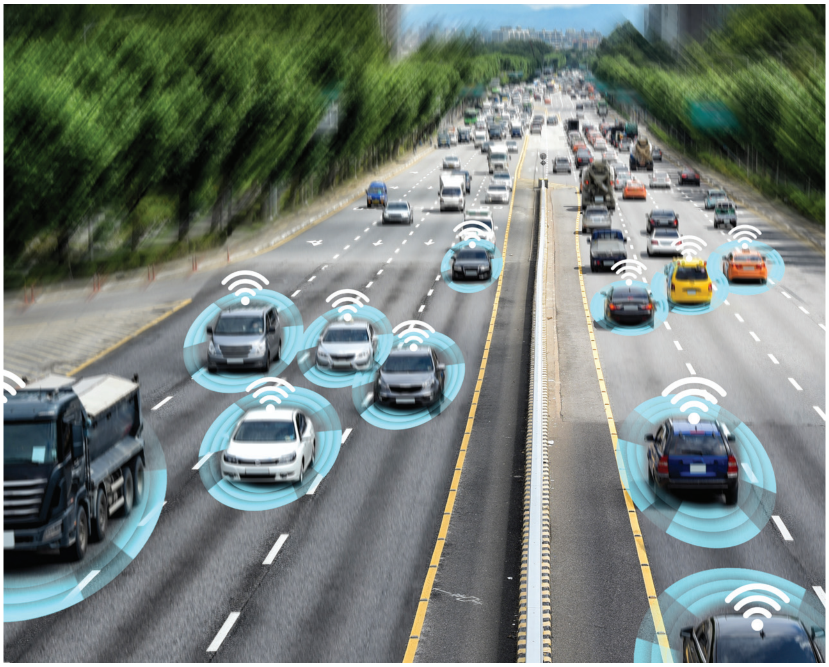
In a 2020 survey that asked international consumers about powertrain preferences for their next vehicle, 59% of respondents in Japan said they would choose hybrid electric or battery electric. This was also true for 52% of consumers in China, 48% in South Korea, 40% in Germany and India, and 35% in the U.S. Alternatively, more than half the respondents in India and the U.S. wanted their next car to use gasoline or diesel.

While alternatively powered vehicles continue to gain in popularity, it comes at a price. According to Craig Zardus, Global Sales Manager in the automotive segment at Parker Hannifin's Engineered Materials Group, "OEMs have to figure out how to meet government-mandated efficiency standards and what the cost will be to the consumer. Electric vehicles have always been more expensive than those powered by internal combustion engines, so is the consumer willing to pay the additional $7,000-$10,000 upfront, or will the government continue to provide incentives? Fuel cell technology is yet another alternative power source for vehicles and has been under development for years but is considerably more expensive than electric vehicles (EVs)."

Advances in electric vehicle battery technology are expected to increase the range a car can travel when fully charged, which is the biggest barrier to widescale adoption of electric cars. The lithium-ion batteries used today have short life cycles and a history of overheating, but they are being improved. Further technology improvements are expected to make batteries safer, cheaper, and faster charging, in addition to having higher energy density that will increase their range. Two new technologies under development that could deliver these properties are solid-state and lithium-silicon batteries. Both could reach commercialization around 2025-2026.

Automotive connectivity will continue its rapid growth through an increasing variety of installed sensors and the global rollout of 5G networks. One global consulting firm predicts that 5G-connected cars will grow from 15% today to 74% in 2023 and 94% by 2028. In addition to giving passengers Internet

access for communications and entertainment including their apps, sensors can also capture and transmit vehicle location and activity, driving behavior, and information from engine diagnostics. Current legislation in Europe requires all new cars to have a system that contacts police when the car has been in an accident.



In the future, cars with 5G connectivity will be able to sense their local environments using information from cameras, lasers, radar, and from the cars around them. Through communications with cloud-based platforms, they will keep drivers better informed about road and traffic conditions. These capabilities will also be essential to the operation of autonomous cars in the future.

The consensus is that **fully autonomous cars** are still years away from widespread adoption. Additionally, there are still legislative, infrastructure and technological barriers to overcome. Based on a 2020 survey, almost half (48%) of U.S. consumers believe that self-driving cars will not be safe, compared with 58% in India but only 35% in China. Along with the Americans, respondents from Japan, Germany and South Korea were equally wary of safety. "Today, the conversation has turned to enhanced mobility, or ADAS (advanced driver-assistance systems)," says Messina. "This is where the computer is not driving the vehicle for you but helping with things like collision avoidance. You have sensors and hear beeps to warn you when other cars get too close, or when you lane-drift. All these electronics are packed into vehicles working together and communicating to improve safety, but you can end up with electromagnetic interference (EMI) and all of that has to be shielded out for the technology to function properly."

Shared mobility, also known as **ridesharing,** is defined as people using technology to share a fleet of decentralized vehicles on demand. This is a growing global trend in densely populated areas that allows people to pay for short term vehicle rentals, primarily cars, e-scooters and e-bikes, parked in different locations around the city. Cities generally favor ridesharing because it reduces traffic congestion and pollution (particularly if shared cars are electric), increasing the quality of life for residents.

For millennials, in particular, ridesharing makes sense. "A lot of millennials live in cities and tend to carry higher debt compared with previous generations. As a consequence, they're buying fewer cars and look to alternative forms of transportation such as mass transit and ridesharing," says Zardus.

While shared mobility is popular in Europe, it has remained stagnant for over a decade in North America due to a combination of factors. It was particularly hurt by the entry of app-based ride-hailing services, higher than expected operating costs, and lower than anticipated adoption by the public. But Will Shurtliff, Global Sales Manager of Vehicle Electrification at Parker's Engineered Materials Group, says OEMs remain focused on it as a longer-term trend.

"It wouldn't surprise me at all if it grows continuously from here. But it's not going to happen overnight and won't be fully realized until autonomous vehicles are a reality." **Mobility-as-a-Service (MaaS)** is a potential future trend for cities. It organizes various transportation options for customers under a single app and payment system. However, it has proven difficult to gain acceptance from transportation providers.

Like many industries, transportation will play a leadership role in reducing greenhouse gases that contribute to global warming. Government standards and corporate initiatives will continue to lead the industry to ongoing innovations that reduce emissions and improve fuel efficiency over time. Likewise, the ongoing digital transformation of our world, including greater connectivity through cloud-based platforms and the Internet of Things, will continue to be among the key drivers of improved safety, efficiency and productivity in the transportation industry for many years. In the end, this will put engineers who develop the most innovative technologies in the driver's seat.

About Parker

Parker is the global leader in motion and control technologies with expertise in hydraulics and pneumatics, filtration, electromechanical, climate control, fluid and gas handling and aerospace. For over 100 years, Parker has contributed to the success of its customers by enabling engineering breakthroughs that lead to a better tomorrow.

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